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Verification of Kando requirements in the Kando understanding support process using DOE and bioinstrumentation

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Abstract

Understanding customer requirements is most important for a conceptual design. Successful companies are providing the highest quality service by which customer receives a satisfaction through the Kando experience. Thus, an element of customer satisfaction is necessary for the great success in business. Therefore, authors have proposed the Idea Creation Support System (ICSS) ― for an idea creation to the Kando understanding process through WOM (Word Of Mouth) effectiveness. In this paper, we propose an assessment system of the Kando understanding support process through the V-model with V&V (Verification & Validation) of this process for ICSS. We confirmed the desirable process for drawing the Kando requirement and the activation of a left side prefrontal area showed the positive expectation for a scene which assumed from a Kando requirement through the V-model with V&V as the assessment system.

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Keywords: Assessment system; Conceptual design; Kando understanding process; Idea Creation system

1. Introduction

For providing an attractive product to customers, customer requirements of a product have been understood, and are needed to deploy to design and development processes. Moreover, factors of effectiveness to an attraction of a product have depended on an inspiration and product knowledge deeply in a conceptual design

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process of making a product concept. Thus, a wide range of customer requirements in the conceptual design process is needed to understand, and problem solving is carried out to its requirements. In addition, successful companies are providing the highest quality service by which customer receives a satisfaction through their new experience. Thus, the element of customer satisfaction is necessary for the great success in business.

From these backgrounds, concept design process supporting methodologies have been studied by many researchers in various application areas in research of creativity or engineering design. Especially in it, the computer aided engineering design has the theory of inventive problem solving (TIPS) and the engineering design methodology (EDM) .

In TIPS, Altshuller's TRIZ (referred to as Classical TRIZ) is the most prominent theory[1]. And he defined TIPS as being not "Problem Solving by Trade-Off", but "Contradictions Solving (it is to solve the contradiction which will worsen other attributes, when it is tried to improve a particular attribute)". Classical TRIZ draws on a design solution using the problem solving techniques, such as the principle of the invention and the contradiction solving matrix, according to ARIZ[2,3]. However, ARIZ is often said that it is a complicated and a difficult process which the only TRIZ specialist can use[4]. To improve this difficulty, Systematic Innovation[5] and USIT (Unified Structured Inventive Thinking)[6] were proposed.

In EDM, Pahl et al. have proposed the systematic approach (referred to as P&B method)[7], and Suh has proposed the thinking process using axiomatic theory as Axiomatic Design[8,9]. Additionally, for generating innovation, Design Thinking has been proposed by Brown[10]. He believes that innovation is powered by a thorough understanding, through direct observation, of what people want and need in their lives and what they like or dislike about the way particular products are made, packaged, marketed, sold, and supported[10]. Therefore, Design Thinking is defined by him and IDEO as a discipline that uses the designer's sensibility, and as methods to match people's needs with what is technologically feasible and what a viable business strategy can convert into customer value and market opportunity[10]. In addition, research of aiming to explore and evaluate creativity in parametric design by the framework for evaluating creativity and the coding scheme for exploring the parametric design process via protocol analysis[11], and exploration of the process of design concept identification and addressing the issue of identifying design concepts in free-form text through examining the agreeability between human coders and performing a language analyses[12] et al. are existed.

On the other hand, for supporting an innovative creation, the authors, Hasegawa et al. defined the creative thinking process as the creation of a new combination of existing elements, which is believed in having an edge on others, for user― designer or development team ―itself. And, it needs to mobilize user's knowledge and know-how, additionally, other things beyond them. The solution was drawn on from its process is defined as the design solution with an innovative creation. Moreover, its process demands to be supported with no depending on user's sensibility or knowledge. To satisfy these requirements, Hasegawa et al. have developed the thinking process of the Creative and inventive Design Support System (CDSS), and have evaluated the validation of CDSS's process by using quality engineering[13]. As described above, research on the many problem-solving processes for supporting conceptual design and creativity's research have been performed. However, requirement understanding methodologies in order to create new value through customer experience is not clearly defined in a conceptual design support process.

For this challenge, Sato and Hasegawa proposed the process of considering the customer's Kando in the problem understanding of CDSS[14]. Kando is Japanese word for the simultaneous feelings of deep satisfaction and excitement. The authors explain the Kando definition through the emotional design and AIDEES model for a consumer behavior understanding as follows.

According to the emotional design, Kando is considered the re-evaluated result through comparing joy in the behavioural level with past experience in the reflective level[15]. A similar theory is shown also in brain science[16]. Moreover, as for Kando, the surprise with unpredictability is contained[17]. In this study, Kando has been defined as "Kando is generated by the interaction of the behavioural level and the reflective level, when a favorable experience with a surprise is larger than a past experience into the re-evaluated process". Moreover, the

AIDEES model[18] as a consumer behavior model has been modelled with "Consumers use care with things, attend to them, desire, experience their brand, become enthusiastic through their experience, and consumer's Kando is told to consumers and shared". When sharing, information on products is given by Word-Of-Mouth (WOM) communication. Thus, an attractive product is things where customers did Kando through consumer behavior. Kando is generated through experience as shown in Fig. 1.

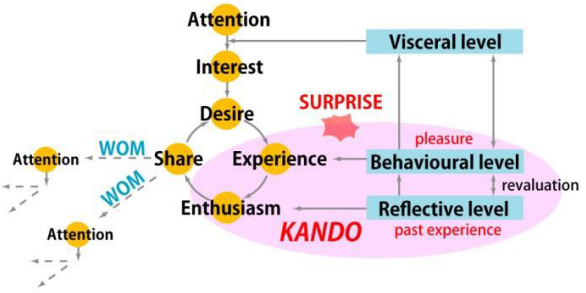


Fig. 1. Definition of Kando through the emotional design and AIDEES model.

Since Kando has been generated by an experience with a surprise, Sato and Hasegawa considered that Kando, which the consumer by oneself has not noticed, can be obtained by extracting a reason of surprise, an element of surprise, an element of experience, and a past experience for comparison. These elements and reasons are dealt in as the Kando requirement, and it is one of the elements should be taken into consideration in a problem understanding process. Therefore, Sato and Hasegawa have proposed the Idea Creation Support System (ICSS) —for an idea creation to the Kando understanding process through WOM (Word Of Mouth) effectiveness[19]. And, ICSS consisted of Kando understanding support process and CDSS.

In this paper, we conduct to verify the Kando requirement through the V-model with V&V (Verification & Validation) assessment process. As the result of verification, we confirmed the desirable process for drawing the Kando requirement and the activation of a left side prefrontal area showed the positive expectation for a scene which assumed from an Kando requirement.

This paper is organized in the following manner. Chapter 2 explains outline of the Kando understanding support process in the ICSS. Chapter 3 verifies the Kando requirement using Design of Experiment (DOE) and bioinstrumentation via measuring the amount of change oxy-Hb (oxygenated hemoglobin) and deoxy-Hb (deoxygenated hemoglobin) by using fNIRS (functional Near-Infrared Spectroscopy). Chapter 4 provides some brief conclusions.

Nomenclature	
CDSS	Creative and inventive Design Support System
ICSS	Idea Creation Support System
WOM	Word Of Mouth communication
oxy-Hb	Oxygenated hemoglobin
deoxy-Hb	Deoxygenated haemoglobin
DOE	Design of Experiment
fNIRS	Functional Near-Infrared Spectroscopy
V&V	Verification & Validation

2. Outline of the Kando understanding support process

To gather the Kando requirements through WOM communication in the Kando understanding support process (Fig. 1), Sato and Hasegawa have introduced World Café methodology[21]. This methodology is expected to simulate WOM's situation. World Café in the Kando understanding support process is organized using these rules: The theme of the discussion was "What are things with Kando?". In Round 1, participants write things with Kando—elements of the reflective level; an opportunity picked up things, an impression, and an expectation—on a sheet of paper. In Round 2, participants write down Kando requirements—a thought when they had Kando, a past story of personal experiences, an environment—in the behavioural level via the User-centered design. Additionally, the Kando requirements are grouped by the classified table of Kando words as shown Table. 1 [20]. In Round 3, participants write down requirements which connect Round 1's things and Round 2's requirements. In the final Session, participants write important impressions and words from the Kando table (See Table 1) on sticky notes. All sticky notes are attached to the final sheet with the Future-Past and the Share-Individual axis. Through these rounds, we are able to define Kando requirements using these sheets. Obtained Kando requirement and customers needs are set into Requirement-Solution's QFD matrix as the analysis results for the problem understanding process of CDSS. Defined problem, i.e., requirements can be solved using the translated design solutions via ideas were gotten by the problem solving process of CDSS. This outline of Kando understanding support process in the Idea Creation Support System is shown in Fig. 1.

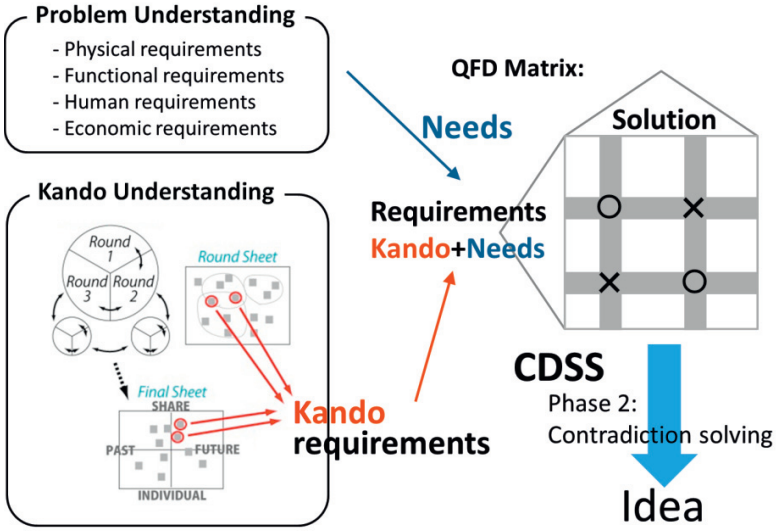


Fig. 2. Kando understanding support process in the Idea Creation Support System.

Table. 1. Classification of 150 Kando words[20].

Major Class		*Middle Class*	*Representative words*
Receptivity		Abundance	Fill one's heart, Love, Good, Tears
		Relish	Heart-warming, Thank you, Serenity
			Sink deeply, Tears of gratitude, Twilight, Lonely, Touching
Expressivity	Positive emotions	Fascination	Be fascinated, Beautiful, Majestic, Silent in spite of oneself
			Touch a person's heart, Heart becomes hot
		Excitement	Exciting, Wow, Pound a heart, Want to say somebody
		Delight	One's heart jump, Tasty, Sympathy, Hot dog!, Fulfillment
			Delight, Hooray, After great pains
	Neutral/negative emotions	Grief	Feel shivers down one's spine, Panic, Surprise, Tension
			Cannot bear, Heartlessness, Tremble, Wailing,
		Awakening	Clutch one ' s heart, Heart is beating, Tremulous, Get goosebumps
			Come to one's senses, Unexpected, Speedy, Big

3. Verification of the Kando requirement

In this study, we develop the assessment system for Kando understanding support process based on the combined procedure of V-model and Verification and Validation (V&V) used as a quality assurance process of Software, Mechatronics, and Engineering Simulation. This assessment system is shown in Fig. 3. The process of the left-hand side of Fig. 3 is the Kando understanding support process. This conducts the definition of Kando requirements on QFD matrix of CDSS through gathering, analyzing, classifying by Kando words, and selecting Kando requirements via World Café methodology. To solve these defined requirements, ideas are generated at the bottom step. From the lower right step of Fig. 3, the verification of obtained Kando requirements, and the validation of whether the generated ideas are appropriate idea are carried out.

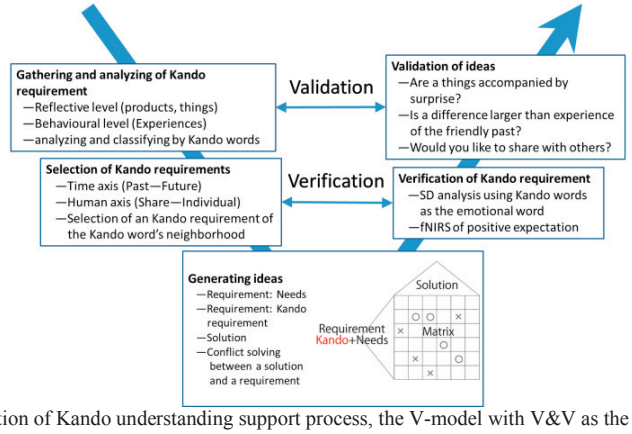


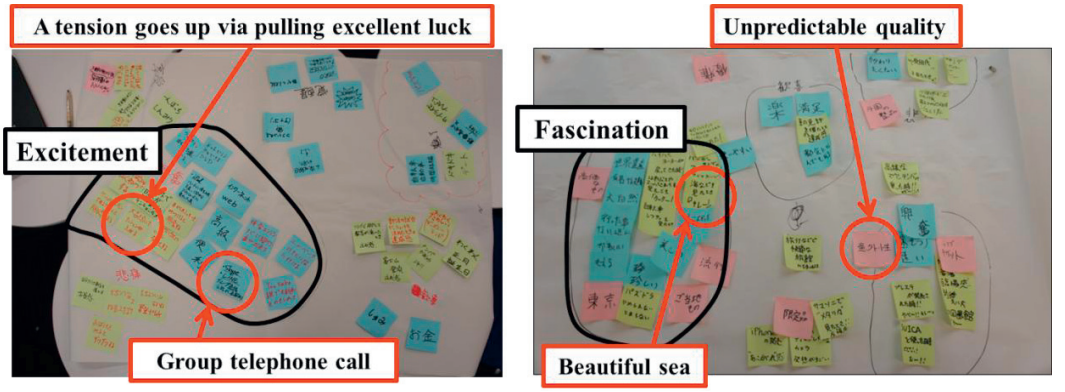
Fig. 3. For verification of Kando understanding support process, the V-model with V&V as the assessment system.

In this paper, for the verification of Kando requirements, DOE was carried out. This assessment using DOE evaluated "Could Kando for oneself be provided?" by five-grade evaluation using Likert scale: "5: think so very much," "4: think so," "3: have no preference," "2: don't think so," and "1: don't think so at all." Moreover, the desirable Kando requirement was verified through an evaluation of both an emotional effect and a positive expectation (prediction)—the activation of a left side prefrontal area in a brain[22,23]—by the hybrid verification method combined Semantic differential scale (SD) method and fNIRS.

3.1. The gathering Kando requirements

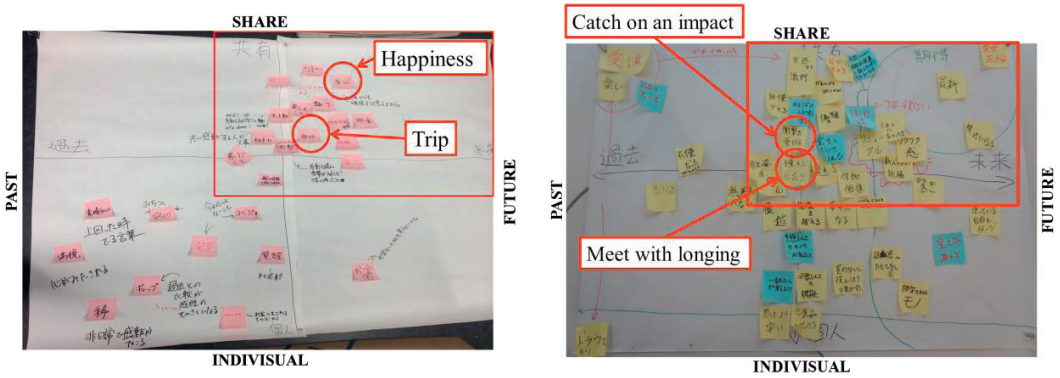
The World Cafés of the Kando understanding process were performed by students as participant on three trials. Here, two cases of them are shown. The participants were consisted of 21 students (15 male and six female students) for the 1st case, and 13 students (12 male students and one female student) for the 2nd case, respectively. In the 1st case, four working tables of 5-6 per one table have been arranged, and the 2nd case has arranged three working tables of 4-5 per one table. Fig.4 and 5 are shown the round 3 sheets and the final sheets of World Cafés.

From the round 3 sheet of the 1st case in Fig. 4 (a), many candidate elements for Kando requirement were placed in the surroundings of "Excitement" at the sheet which carried out the grouping in the Kando word of the Kando word classification table. Furthermore, the round 3 sheet of the 2nd case in Fig.4 (b) also had many candidates in the surroundings of "Fascination". Next, in the final sheet of Fig.5, Both cases brought a result of many candidates gathered mostly at "Future × Shared" area. Therefore, taking notice of this area, when the Kando words were extracted, in the 1st case, "Fascination" and "Excitement" were obtained, and "Happiness" and "Trip", as the elements of the Kando requirement, has been extracted from those surroundings. And in the 2nd case, "Fascination" and "Excitement" of the Kando word also were taken out. "Catch on an impact" and "Meet with longing", as the elements, were obtained from the surroundings of them. Moreover, through taking notice of "Excitement" with many candidates for Kando requirement, for example, "A tension goes up via pulling excellent luck" and "Group telephone call" were obtained from the round 3 sheet of the 1st case. In the 2nd case, Kando requirements, such as "Beautiful sea" and "Unpredictable quality", were obtained from "Fascination" with candidates and "Excitement" was focused in the 1st case, respectively.



(a) 1st case; Group telephone call. (b) 2nd case; Beautiful sea.

Fig. 4. Examples of round 3 sheets of World Café in Kando understanding process.



(a) 1st case; Group telephone call. (b) 2nd case; Beautiful sea.

Fig. 5. Examples of Final sheet of Kando understanding process.

3.2. The verification of Kando requirements using DOE

In order to verify "When picked up or experienced things in accordance with element of Kando requirement, Can provide Kando for oneself?", the evaluation is performed using DOE of Quality Engineering. This evaluation assigns three factors, i.e., Factor1: the Kando word, Factor2: time axis and Factyo3: human axis, to the control factors (design factors). These factors used three levels, and the Kando word's level (0:None, 1:Receptivity, 2:Expressivity (Positive emotions)), time axis' level (0:None, 1:Current, 2:Future), and human axis' level (0:None, 1:Individual, 2:Share) were defined. Therefore, the orthogonal array L9(3^4) is applied as shown in Table 2 and 3. The extracted Kando requirements in Table 2 and 3 were combined and were extracted from the final sheet in Fig. 5 and the round 3 sheet in Fig. 4 of the World Cafés.

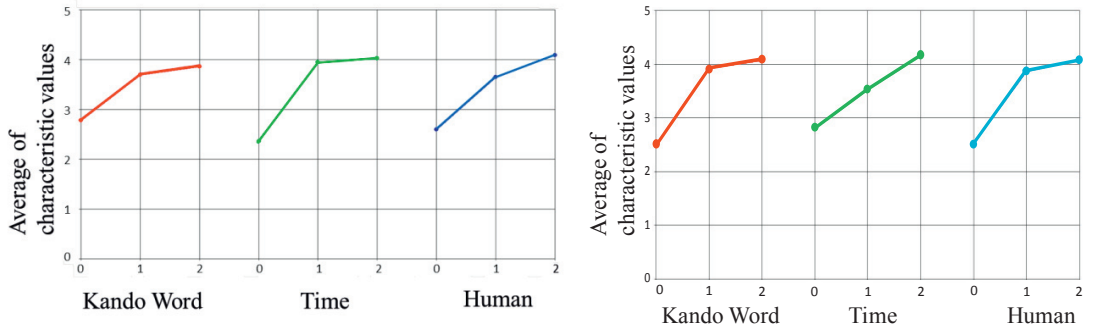
Table 2. The orthogonal array ; L9(3^4) of 1st case; Group telephone call.

Trial	Factor1	Factor2	Factor3	Combination of factor level	Extracted Kando requirement
1	0	0	0	None	None
2	0	1	1	Current ×Individual	Not experienced (things or experience)
3	0	2	2	Future×Share	Would like to provide WOM to people
4	1	0	1	Receptivity×Individual	Feel safe (things or experience)
5	1	1	2	Receptivity×Current×Share	Trip (things or experience)
6	1	2	0	Receptivity×Future	Happiness (things or experience)
7	2	0	2	Expressivity×Share	Rare things or experience
8	2	1	0	Expressivity×Current	Exciting (things or experience)
9	2	2	1	Expressivity×Future×Individual	Thrill of things or experience

Table 3. The orthogonal array ; L9(3^4) of 2nd case; Beautiful sea.

Trial	Factor1	Factor2	Factor3	Combination of factor level	Extracted Kando requirement
1	0	0	0	None	None
2	0	1	1	Current ×Individual	Be likely to lose, if do not buy things
3	0	2	2	Future×Share	Latest (things or experience)
4	1	0	1	Receptivity×Individual	Can not buy things with money
5	1	1	2	Receptivity×Current×Share	Elegance (things or experience)
6	1	2	0	Receptivity×Future	Happiness (things or experience)
7	2	0	2	Expressivity×Share	Empathize (things or experience)
8	2	1	0	Expressivity×Current	Exciting (things or experience)
9	2	2	1	Expressivity×Future×Individual	Fly in the air

Moreover, these Kando requirements were assessed through questionnaires with Likert scale by 20 students as subject. The main effects obtained as the evaluation results of these requirements are shown in Fig. 6. As a result, we obtained the “Expressivity” of Kando word, the “Future” of time axis, and the “Shared” of human axis through picking up the highest characteristic value. We confirmed that the most desirable process to obtain the Kando requirement is drawn from the area of the combination of “Expressivity × Future × Shared”. From this result, we can believe that Kando becomes large through sharing the positive expectation to express between a lot of customers. So, we can draw on the Kando requirements through picking up the elements from both the final sheet and round 3 sheets of each working table. Thus, the Kando requirements, “Group telephone call” and “Beautiful sea", which belong to the area of the combination of “Expressivity × Futrue × Shared” are used in the next section.



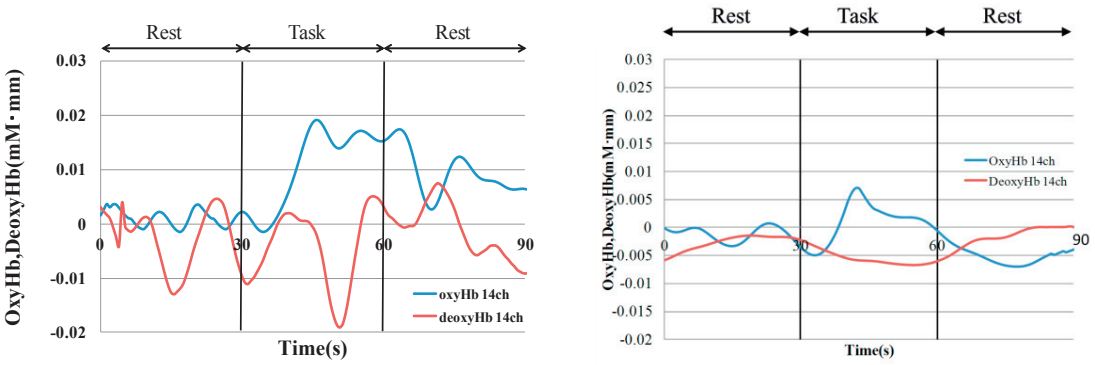
(a) Group telephone call (b) Beautiful sea

Fig. 6. The main effect of Kando requirements for verifying its selection process of the Kando understanding process.

3.3. The verification of Kando requirement using hybrid method combined SD method and fNIRS

fNIRS is a spectroscopic method that uses the near-infrared region of the electromagnetic spectrum (from about 800 nm to 2500 nm). Further, fNIRS brain measurement device is a device for measurement of brain functions by near infrared spectroscopy to measure the concentration change of deoxy-Hb and oxy-Hb in the brain. When the brain is working, oxy-Hb performs the oxygen supply through the capillary, oxy-Hb exceeds deoxy-Hb, and bloodstream increases, brain activity becomes active. fNIRS was used for verifying desirable Kando requirement through an evaluation of a positive expectation (prediction), i.e., the activation of a left side prefrontal area in a brain[22,23].

In this paper, the experiment was conducted to the eight students as a subject in a quiet dark-room to avoid a noise, and shut their eyes close at the time of the experiment. Based on the result of DOE, “Visualize the scene of carrying out a group telephone call in your mind” and “Visualize the scene of seeing a beautiful sea in your mind” were questioned to verify Kando requirement which belongs to the “Expressivity × Future × Shared”. And, the cerebral blood flow at that time was measured using fNIRS. As the result, we showed the average of the cerebral blood flow’s measurement data of eight measurements in Fig. 7. This result consisted of rest phase and task phase every 30 seconds. We confirmed the activation of a left side prefrontal area in a brain as a positive expectation since the oxy-Hb exceeded the deoxy-Hb into the task phase of the experiment.



(a) Group telephone call. (b) Beautiful sea.

Fig. 7. The fNIRS experimental results.

Next, The SD method is a method to quantify the sensitivity information from the results of the answer questionnaire. SD method can be used to measure opinions, attitudes and values on a psychometrically controlled scale. After the measurement of fNIRS, the questionnaire of the SD method for the subject was performed. We pulled out a sensible word to use for an evaluation out of the classification of 150 Kando words, and made this questionnaire. We showed the average of the questionnaire of eight subjects in Fig. 8. A red line and a green line denote results about “Group telephone call” and “Beautiful sea”, respectively. The experimental result of the SD method showed that “Group telephone call” had acquired the high evaluation value by each word. Moreover, the evaluation about “Beautiful sea” turned to the word of the “Fascination” instead of “Delight” and “Excitement”. Because, its evaluation in Fig. 8 denoted "Get excited" and "Heart bouncing" as the sensible words were not which, either. This can be said to be the validated result, because of this extracted Kando requirement from the area of “Fascination” of World Cafés. Additionally, since its measured oxy-Hb concentration increased in Fig. 7, we could believe that “Beautiful sea” was carrying out positive expectation as the “Fascination”.

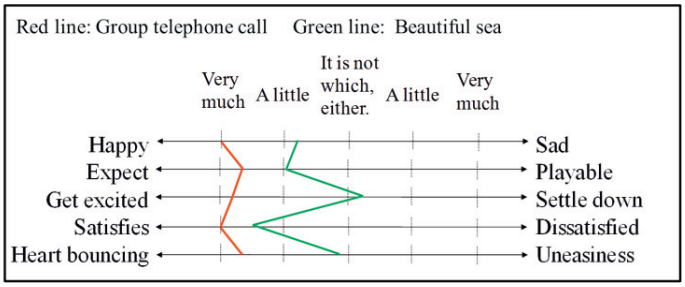


Fig. 8. The questionnaire results by the SD method

4. Conclusion

We proposed an assessment system of the Kando understanding support process through the V-model with V&V for ICSS. Based on the proposed assessment system, we performed the verification of Kando requirement by using DOE and hybrid method of fNIRS and SD method. As the result, we confirmed the desirable process for drawing the Kando requirement and the activation of a left side prefrontal area showed the

positive expectation for a scene which assumed from an Kando requirement through the V-model with V&V as the assessment system. From the above mention, we can describe that the Kando understanding support process of the Kando requirement of ICSS is effective.

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